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Identifying Cost Impacts to Public Storm Water Infrastructure for Campus Development

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This paper will explore the current expansion of college campuses and the impacts that occur to the aging storm water infrastructure. In the past 20 years' colleges have increased in population and there is a growing emphasis being placed on education with the current high school student. To entice new students in this competitive market many universities have elected to expand and update their facilities in an effort to increase their enrollment. By doing so they have exceeded the capacity of the existing infrastructure so to add in their growth they have to develop plans to improve the systems and reduce their overall impacts on the environment (Too, 2012). Storm water structures are a system of pipes and retention practices that are used to remove excess water from an area that could not handle the volume naturally in a time that would not place individuals or property at risk. As pervious areas are claimed by an ever growing society and impervious structures laid down the environments ability to dissipate the waters are reduced and the storm water systems means needs to be increased. Prior to any expansion there should be a well-choreographed plan in place to achieve the goals of growth which do not impact the surrounding areas. Failure to plan can place lives, property, and the contributing water systems at risk of floods, erosion, and contamination. Understanding budgets and planning timelines are essential to planning for this growth. Most campuses plan for 10 years of growth but release work within a fiscal year budget. Combine this with local planning review times that can exceed 6 months for an environmental permit and one can see that there is a balancing act between the funding and the planning and release of contracts.

Key Words: Stormwater, Environmental, Facilities, Site, Planning

Introduction

With student populations growing exponentially every year institutional leaders have identified the need to entice more applicants. To make their campuses more appealing to new students the colleges have expanded and improved their structures to present a new and exciting place to learn. By restructuring aging campuses, Universities have not only increased their enrollment numbers but have placed a higher demand on antiquated storm water systems. Prior to the expansions of the campuses the existing run-off piping was sized to dissipate water from wooded and grassy areas which could accept a certain portion of the storm water (Fischer, Amekudzi, n.d.). The construction of new roads and structures have reduced the ability of the area to accept a large amount of the water which in turn forces the water into the storm water system. The older piping and water retention areas are not equipped to handle the added loads which results in increased contaminants and erosion into the waterways that the storm water empties into. For this reason, prior to any expansion the colleges have to work with the local authorities and develop a plan to improve the storm water management system. There are several means to decrease the effects of every growing colleges and still allow the development to take place which will entice more students.

Campus Growth

University leaders are set with a task of growing their student population which increases the college's revenues every year. The United States Department of Education reported that in 2013 there were over 20 million students enrolled in college. This number has increased by 20% since 2003 and the number of full time students has grown over 22%. These numbers reflect a need to grow their campuses and upgrade facilities to capture this revenue and gain favor with the school's alumni who contribute to a large portion of the college's working capital. At the same time student trends are showing that students are staying in school longer to complete post graduate degrees as their numbers have increased by 24% during this same time period.

In 2015 college campuses budgeted over $11.6 billion for building construction, and $8.7 billion was for new structures with the remaining funds allocated to renovations and repairs (Abramson, 2015). To put this in perspective, colleges expanded their campuses with roughly 175 new structures with a median of 50,000 square foot each. This equates out to over 8,750,000 square foot of impervious surfaces that will now need to be accounted for in new or existing storm water systems. Identifying the number of impervious surfaces is only part of the equation for planning a storm water system that will allow building and surface runoff to enter back into the environment. Certain roofing materials can degrade from rain events and should be filtered prior to being allowed back into the waterways. Human factors such as trash and oils need to be removed before they are released into an ecosystem that could be impacted.

As demonstrated in figure 1 most campuses initiate planning for expansion 3 years prior to actual shovels hitting the ground. The first phase is identifying the needs of the community and understanding the impacts expansion can have on aging and outdated infrastructures. The second and third phases of the planning attempt to not only make the infrastructure large enough to handle the current plans but allow for growth within reason. At this time the designers for the current expansion work with the master planners for the campus and implement designs that will reduce impacts to existing buildings in the event that funding and needs allow for additional structures (Ogurek, n.d.). By the final two phases the plans are in place and the local Authority having Jurisdiction (AHJ) have agreed to allow the development to proceed. At that point the campus is awaiting funding and prioritizing which buildings have a more pressing need within the budgets.

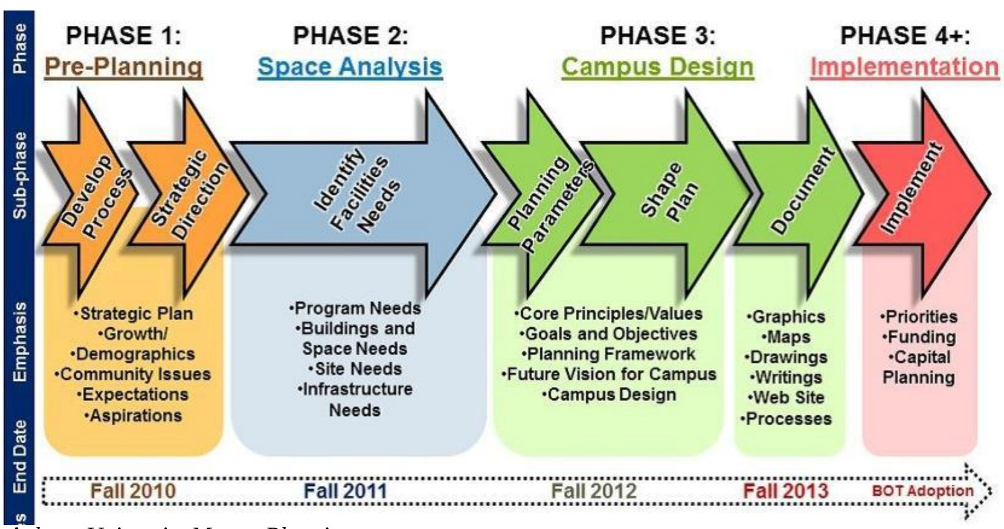

Figure 1: Auburn University Master Planning

Environmental Planning

Understanding the existing conditions is imperative before starting any planning of an expansion project. First we must look at the surface areas and their ability to dissipate water and contaminates before they would reach a waterway (Love, et al. 2010). Then we must look at the existing storm water system, is it adequate under its current state and will it be able to handle the new structure. In many cases there is no storm water system in place because the areas to be developed have had no need for one. Once the evaluation process has been completed the engineer should calculate the loads from the new structures and make a recommendation to the local authority having jurisdiction. The Department of the Environment has given authorities to local jurisdiction to oversee the protection of the United States waterways and wetlands.

The Environmental Protection Agency (EPA) has been given the task of protecting the United States waterways and contributories under the Clean Water Act (CWA) of 1972. The CWA states that the EPA most limit if not eliminate any contaminates to maintain water quality before entering waterways and other protected lands. There are four factors of water quality standards: 1) Designated uses; 2) Water quality criteria; 3) Anti-degradation policy and 4) General policies (U.S EPA, n.d.). Designated uses are evaluated every 3 years with a use attainability analysis for all water sources that are being used for purposes other than fishable and swimmable. During the analysis the general health of the water is evaluated to ensure that the ecosystem has not been harmed. The second factor is the water quality in which a numerical test can be given to the water to see if there have been any changes in toxicology to the water. These tests give a clear defensible value to data collected over different periods of time. Anti-degradation policies are a 3 step procedure to ensure water quality whenever activities are schedule to take place around navigable waters. Step 1, identifies the waters current uses and clarifies that future use will not impact the existing conditions. Then step 2, maintains and protects water bodies with existing conditions that are better to support CWA. The 3rd step identifies waters with outstanding national resources and determines protective measures needed to make sure that the waters with the Nation's highest ecological significance are not affected.

A key component in the partnering between developers and the EPA and their authorities is the Storm Water Pollution Prevention Plan (SWPPP). The SWPPP is the contractor's best effort to identify any area on their site that could have the potential to affect the environment. Once the contractor develops their SWPPP they must present their documents to the authority having jurisdiction and get approval to proceed. Figure 2 shows the Auburn University for a construction site and some of the Best Management Practices (BMP) that can be used to contain contaminates on their site. Note that the site access cannot be sealed, the contractor needs to find a way to minimize construction materials from leaving their site.

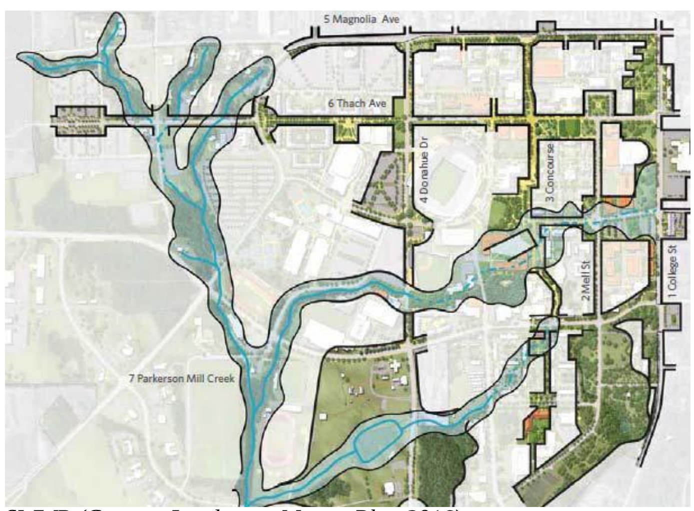

Figure 2: Auburn University SWWP (Campus Landscape Master Plan 2016)

Impacts to Environment

In order for the SWPPP's to be affective all environmental impacts need to be understood and means to reduce them should be implemented. Environmental Impact Assessments (EIA) were derived from the

Europeans Committees Directive to ensure that projects that could impact the environment receive the proper evaluation prior to the start of work. Within the EIA there are two paths that need to be reviewed, those that have impacts or possible impacts and those that have no impacts. Once all aspects of the project have been reviewed, we can determine if there will be any detriments to the ecosystem. If it is determined that there will be, then an action plan needs to be implemented to reduce or neutralize the harmful factors. The second path would allow the reviewers that there is minimal to no risk and that there should be no actions needed. Once the EIA has been completed and all risks assessed the authority can make a determination as to allowing the work to proceed.

Construction waist is a major contributor to storm water pollution, without proper maintenance jobsite materials can flow from a project site directly into a waterway and impact the ecosystem in ways that it may not be able to recover from. Undisturbed earth with vegetation is a natural means to filter storm water and prevent the majority of contaminates from entering our water systems. Once those sites are disturbed for construction the loose earth cannot withstand the forces of water and the sediment will be carried off of the site. Prior to any soils being disturbed on a site the erosion and sediment controls need to be established and approved by the local AHJ in a best effort to minimize the risks (Snider, n.d.).

Construction Controls

The construction industry and local authorities rely on Best Management Practices (BMP) for minimizing the threat of contaminating waters from construction sites as shown in figure 3. The first line of defense is the perimeter controls for the site and attempting to keep the projects soils and construction debris from migrating to adjacent properties. Silt fences, construction entrances, and existing landscape are the most common methods and they can be easily adjusted to withstand greater threats if needed. Silt fences are placed around the perimeter of the project in areas that materials will gravitate to and depending on the level anticipated the fence can be made of fabric or it can be reinforced with chain fencing. Throughout the project this fence needs to be monitored and the contractor has the authority to increase the amount of controls needed to ensure the project site stays secured. The second aspect of perimeter controls is that of the construction entrance and establishing a means to reduce dirt from being tracked off of the site. For this the most common BMP is to use large stone or gravel at the construction entrance to displace dirt off of the construction vehicles tires. If during the project the spoils appear to be leaving the site through this area the contractor can increase the size of the stone, elect to clean the adjacent roadways, or install a cattle guard in an effort to maintain their site. The third and most beneficial to the contractor is the use of existing natural landscapes to contain their site. If the site has a gradual slope in one direction the contractor may not need to install silt fencing on the uphill side of the project. The same holds true with other features that will naturally contain materials on the site, for this the topography of the site can be used to reduce costs while still protecting the environment.

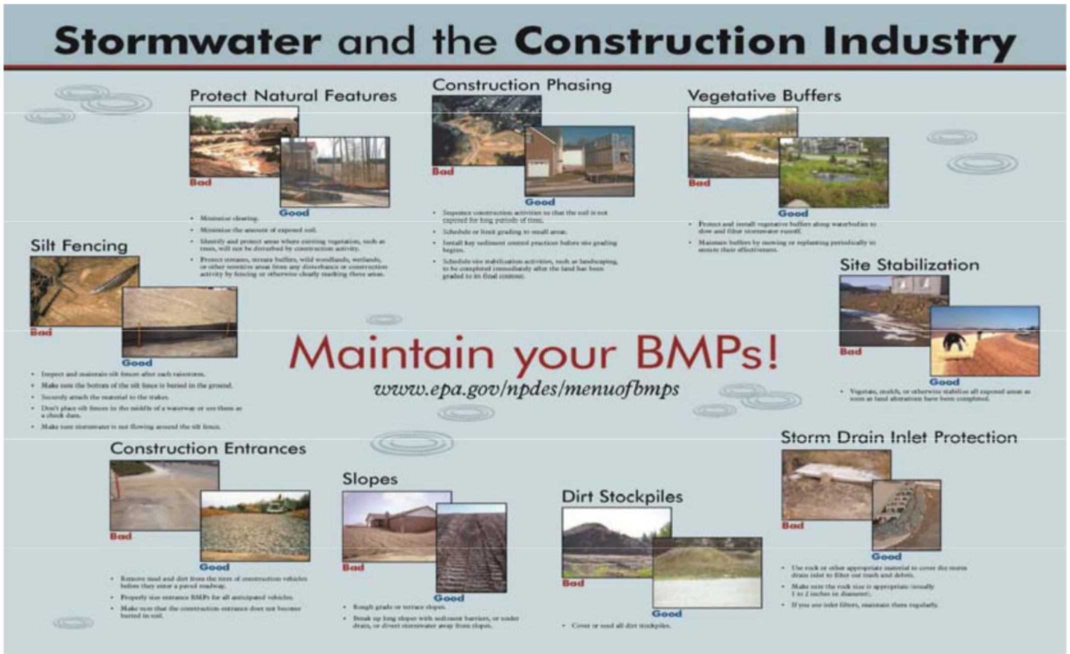

Figure 3: Best Management Practices (www.epa.gov/npdes/menuofbmps)

Once the project has installed the perimeter controls they need to establish controls within the site that will aid in the event of more substantial weather event; these include stabilizing soils, filtering water, and disposing of spoils that are not needed on the site. During the course of a project excavation stockpiles exist and can become a hazard if they are left for large durations of time. The loose earth does not have the ability to withstand large rain events and depending on the amount they can overtake perimeter controls and leave the site. For this reason, the EPA has established BMP's that require stockpiles to be stabilized within 7 days of them being placed. Stabilization consists of securing the loose soils by means of attempting to grow vegetation on the piles; this can be accomplished by seeding and straw, or rolling netting with seeds embedded within the nets. Once the soils are controlled the site water needs to be managed to reduce contaminates from leaving the site. The topography of the project is essential for identifying where and how the water on a project will move, then establishing means to control it. Some of the BMP's for water management are establishing sediment ponds, dewatering plans, sediment tanks, and inlet protections. Identifying a low area in the site can be an ideal location to establish a temporary or permanent sediment pond. Sediment ponds are areas that the project can drain to and retain the waters to allow the sediment to settle and clearer water to drain into a storm water pipe. These ponds are generally a permanent structure once the project is completed to control the new impervious structures; the final location can be adjusted prior to the construction being completed. There are several plans that can be established for each project depending on their size. Water can be managed onsite as stated earlier with the retention ponds or they can be contained and removed with trucks if needed. The site will determine what the contractor needs to do to control their water. Smaller projects can use wells and sediment tanks or bags to hold the water and then filter it prior to releasing it off the site. Other projects can install inlet protections to remove silt and sediment from the waters prior to returning to the storm water system.

Understanding the requirements needed to control a construction site are imperative when developing the plans for construction. First, the size of the building is not the size of the construction site. The contractor will need to room to work and bring materials onsite without impacting the surrounding areas. The AHJ may limit the amount of disturbed earth within a certain storm water system. Planning multiple projects side by side might not be allowed because there will not be enough availability to protect the environment. IF there is a master plan for the development, the university may wish to hold the overall Notice of Intent (NOI) which states to the AHJ that you will be responsible for maintaining the controls and protecting the area. If the campus is holding single NOI for the area they can elect to parcel the campus up into sites and transfer the NOI to the contractor so they are at risk for their site. At the same time the AHJ will look to the college to oversee the work and help them in the quality assurance of the storm water management.

Materials and Methods for Improving Storm Water Systems

Low Impact Development (LID) methods for improving storm water management is the area that university leaders can have the biggest impacts in their campuses development (Wittenbrink, et al. n.d.). Developing a master plan that looks 20 years into the future will aid in the overall wellbeing of the campus. The materials that can be used to improve storm water management can also help the campuses to reuse resources that previously considered waist. Many colleges are starting to implement storm water retention systems that collect storm water and reuse it when water supplies are low or need to be reserved. Figure 4 shows a storm water retention basin that holds excess runoff during a rain event. These basins can hold the water until the event is finished and release the waters into the system once it can handle the excess volumes by doing this it helps the reduce the volume of water at a time that the pipes are at their limits. An additional feature that the catch system can be used for is to reuse the water for the campus irrigation system. During a time of drought or simply to save the college money, the water could be pumped back into the non-potable water supply and reused to water the vegetation (Paz, Beamen, Kramer, n.d.).

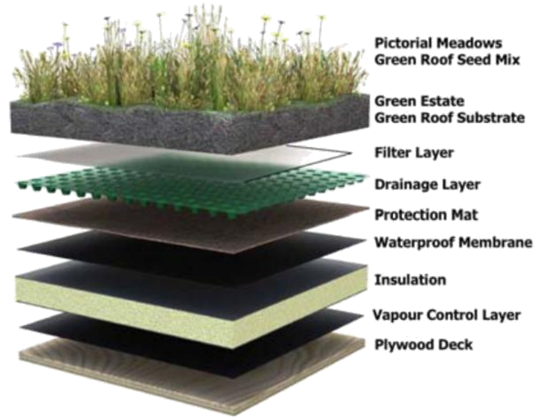

Figure 4: Storm Water Retention Basin (www.qualitysitework.com) *Figure 5: Green Roof (impressivemagazine.com)*

The second aspect of designing new structures is finding ways to implement Green methods and materials into the overall design. Years ago there was a push for Green Roofs and placing vegetation onto the roof in an effort to better the environment. In theory this was a great idea but there were additional efforts needed to maintain those roofs, for instance they needed to be watered if they were to stay green (Fleischner, et al. n.d.). Today engineers have developed Green Roofs that catches the water and is self-maintaining. Figure 5 shows how the Green Roof is added to a roofing system therefore does not place the roof at risk while giving the added benefit of helping the environment. The small reservoirs under the plants holds the water which is returned to the plants when the substrate starts to dry out.

A key contributing area to storm water failures is the addition of impervious surfaces into storm water systems that cannot handle the additional volumes. The development of new areas used to mean that the green areas were removed and replaced with hard structures that would not allow the land to accept the moisture needed to limit the function of the storm systems. After years of needing to improve infrastructure many campuses implemented the use of open pavers as a means to provide walking paths that would allow water to penetrate. Those pavers helped with the reduction of water being added to the storm system but required more maintenance and did not offer the even walking surfaces needed for safety. Today many institutions are looking back to an old solution and installing pervious concrete. This new solution utilizes a version of concrete that was used in Europe hundreds of years ago which created 15-25% voids in the concrete. These spaces within the concrete allow water to pass directly through as in figure 6 so that water does not travel down the surface and enter back into the earth rather than the storm water system.

Figure 6: Pervious Concrete (www.pervious.info)

Figure 7: Baffle System (www.prestogeo.com)

Erosion of storm water outfalls becomes a concern when increased volumes are applied and the system is not able to reduce the turbidity of the water. As additional water is introduced into smaller pipes the force generated by the volume is increased and as the water leaves the pipes it becomes more destructive at the outfalls. To counter this engineers have implemented baffling systems to reduce the force and allow sediment to be deposited within the pockets of the system. Figure 7 shows a newly engineered system that can be added to any outfall area and will help to slow the waters before it erodes the banks and increases sediment into the water ways. There are several additional types of baffling systems that can be implemented within the storm water system and all are intended for the same purpose of reducing the force of the water and removing as much contaminates as possible before destroying the waterways.

Conclusion

As discussed college campus can have huge impacts to existing storm water systems and therefore need to work closely with local jurisdictions before any additions can be made. Once the local AHJ has agreed to the additions the designers must partner with the master planning organizations to develop a better understanding of possible future growth so that improvements can be made that will allow for easier expansions. These processes can take as much as 3 years to work through the systems and develop the plans that are needed to allow the college to expand and capture part of society's fastest growing population. Once all plans have been approved and the university has identified the priority and funding for the new buildings design for the project can take place. Within this phase the architect can implement innovative designs that can reduce the impacts to the system and aid in their overall campus health (Cheema, Irfan, n.d.). After the design is completed the contractor is called upon to implement BMP's to work with the AHJ's and reduce construction waist and minimize impacts to the surrounding areas. The total time duration for campus expansions can take as many as 4 years from time of project is identified as a need and construction starts. Universities have to plan well in advance for construction and identify additional funding outside of the cost of the project to upgrade aging and undersized infrastructure systems if they intend to grow the campus.

References

Abramson, P. (n.d.). Campus Construction 2015 -. Retrieved July 27, 2016, from https://webcpm.com/research/2016/02/campus-construction.aspx

Cheema, S. N., & Irfan, M. (n.d.). Water Reclamation Strategies in the Built Environment—A Framework and Case Study of a University Campus. In *Construction Research Congress 2012* (pp. 2011–2020). American Society of Civil Engineers. Retrieved from http://ascelibrary.org/doi/abs/10.1061/9780784412329.202

Fischer, J. M., & Amekudzi, A. (2011). Quality of Life, Sustainable Civil Infrastructure, and Sustainable Development: Strategically Expanding Choice. *Journal of Urban Planning and Development*, *137*(1), 39– 48. http://doi.org/10.1061/(ASCE)UP.1943-5444.0000039

Fleischner, M. P., Caine, M., Koza, M. B., & Stout, D. J. (n.d.). Reuse of Wastewater for Sustainable Development of a Research and Development Campus in New Jersey. In *Bridging the Gap* (pp. 1–5). American Society of Civil Engineers. Retrieved from http://ascelibrary.org/doi/abs/10.1061/40569%282001%29304

Love, P. E. D., Edwards, D. J., Watson, H., & Davis, P. (2010). Rework in Civil Infrastructure Projects: Determination of Cost Predictors. *Journal of Construction Engineering and Management*, *136*(3), 275–282. http://doi.org/10.1061/(ASCE)CO.1943-7862.0000136

Ogurek, B. D., & June 24th, 2016. (n.d.). Sustainable Campus Master Planning Concepts for Higher Education -. Retrieved July 16, 2016, from https://webcpm.com/articles/2016/06/24/master-planning-concepts.aspx

Paz, L., Beaman, W., & Kramer, H. (n.d.). Integrated Stormwater Facility Design to Address Hydromodification on a College Campus, Livermore, California. In *Low Impact Development*

2010 (pp. 287–298). American Society of Civil Engineers. Retrieved from http://ascelibrary.org/doi/abs/10.1061/41099%28367%2926

Snider, B. O., & March 1st, 2016. (n.d.). Seeking Approval -. Retrieved July 16, 2016, from https://webcpm.com/articles/2016/03/01/capital-project-approvals.aspx

Too, E. G. (2012). Capability Model to Improve Infrastructure Asset Performance. *Journal of Construction Engineering and Management*, *138*(7), 885–896. http://doi.org/10.1061/(ASCE)CO.1943-7862.0000489

Turner, S. D. O., & Chan, T. C. Y. (2012). Examining the LEED Rating System Using Approximate Inverse Optimization, 241–250. http://doi.org/10.1115/IMECE2012-93116

US EPA, O. (n.d.). Storm Water Management Model (SWMM) [Data and Tools]. Retrieved July 14, 2016, from https://www.epa.gov/water-research/storm-water-management-model-swmm

Wittenbrink, M. M., Timmins, K. J., & Donnelly, Q. L. (n.d.). OHSU Stormwater Management Plan: A Unique Approach to Stormwater Management for Campus Facilities Using Low Impact Development. In *Low Impact Development for Urban Ecosystem and Habitat Protection* (pp. 1–10). American Society of Civil Engineers. Retrieved from http://ascelibrary.org/doi/abs/10.1061/41009%28333%29118